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Causes, consequences and countermeasures of overtaking accidents on two-lane rural roads

Thomas Richter [a], Stephan Ruhl [a,*], Jörg Ortlepp [b], Emmanuel Bakaba [b]

[a]*Technische Universitaet Berlin, Department of Road Planning and Operation, Gustav-Meyer-Allee 25, Berlin D-13355, Germany*
[b]*German Insurance Association (GDV), German Insurers Accident Research (UDV), Wilhelmstraße 43 / 43G, Berlin D-10117, Germany*

Abstract

Overtaking accidents have one of the most serious consequences of accidents on German rural roads. The aim of this project was to determine the infrastructural and traffic related variables which influence the occurrence and consequences of overtaking accidents as well as the overtaking behavior of drivers. Finally, diverse correlations between operational and infrastructural road characteristics and overtaking accidents and driver behavior were found out and a catalogue of measures had been developed. The given recommendations will have beneficial influences on overtaking behavior and their practice will lead to an increase in safety on two-lane rural roads.

Keywords: Accident prevention; traffic safety; overtaking accidents; overtaking behavior; rural roads

1. Introduction and methodology

In 2014, 73,916 accidents with personal injury on rural roads were registered by the police in Germany. Here, 2,019 persons died and other 25,971 persons were seriously injured as reported by DESTATIS (2015). About 6 percent of these accidents occurred due to overtaking maneuvers, but they cause approximately 9 percent of killed and seriously injured persons as analysed with data of DESTATIS (2009). This clarifies that overtaking accidents are one of the most serious accidents on German rural roads.

* Corresponding author. Tel.: +49-30-314-72560; fax: +49-30-314-72884.
E-mail address: s.ruhl@spb.tu-berlin.de

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Due to such statistic values further research activities and analysis on accidents and their influencing factors are an essential part in the section of road planning and road design. The subsequent advancement of guidelines for the construction and operation of rural roads is a significant contribution for improving road safety. In the literature there are mainly older reports on overtaking accidents and overtaking behavior. For the changing of German guidelines for the design of rural road in 2012 new research had to be conducted to assemble actual values on the topic of overtaking on two-lane rural roads. Which road configuration leads to which overtaking behavior and which is critical for accident occurrence is the result of the mentioned project and theme of this paper.

The main result of the research activities was the finding, that there is a lack of unity of road construction (existing sight) and road operation (configuration of the traffic regulation). Within the complex process of overtaking the driver needs support from the road design in the task of driving to avoid errors and accidents. Moreover, a microscopic accident analysis was carried out to identify the essential facts of accident occurrence. Thereby five typical situations were detected and are involved in the further recommendations. In general, a set of influencing parameters for overtaking accidents and overtaking behavior are identified. Finally, this parameters of real overtaking behavior are used to evaluate possible measures empirically.

This paper contains an overall summary of the results of the above mentioned research project. Here, the findings of the literature, the macroscopic accident analysis, the influence of the configuration of the traffic regulation, the visibility analysis and evaluation of road layout, the detailed analysis of overtaking behavior and recommended measures to avoid overtaking accidents on two-lane rural roads are indicated, which are valuable information's for improving road safety. A scheme of the overall project approach and the content of this paper is depicted in Fig. 1.

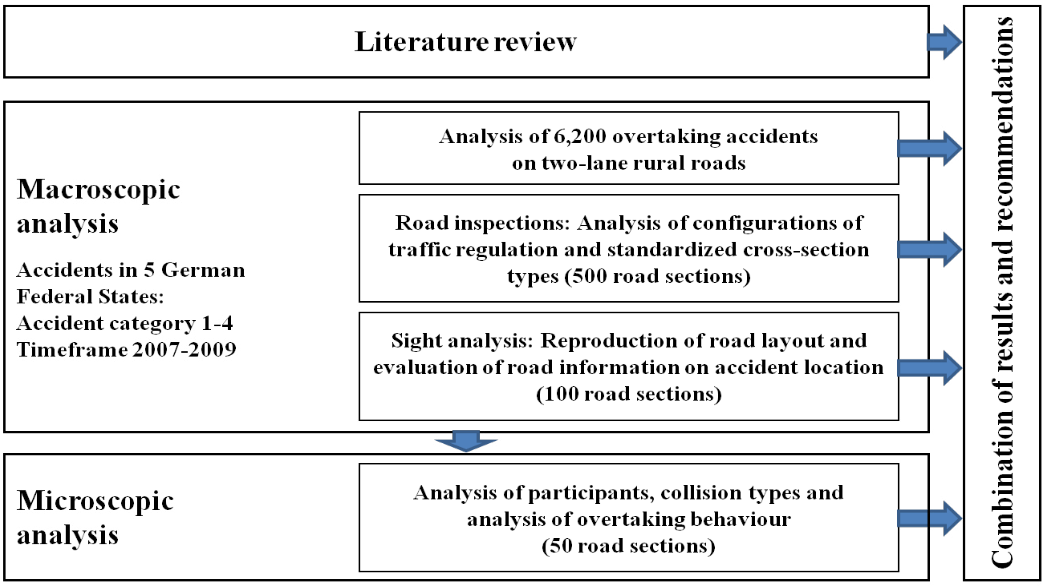


Fig. 1. Scheme of project approach and paper content.

2. Literature review

Overtaking is a very complex driving process with a variety of influencing factors. But the driver is physically and mentally not able to capture all the influencing factors rationally and make a decision based on a weighting. Even overtaking maneuvers under the same boundary conditions and with the same drivers will not be identically, see Netzer (1966). The traffic requirement for overtaking increases fundamentally with increasing speed dispersion in the traffic stream and generally with increasing traffic load. Missing overtaking possibilities can lead to accrued overtaking pressure which can cause risky overtaking maneuvers as reported by Steierwald et.al. (1983). Accumulation of overtaking maneuvers are correlating with existing overtaking sights and are influenced by the current traffic situation as mentioned in Kayser et.al. (1986).

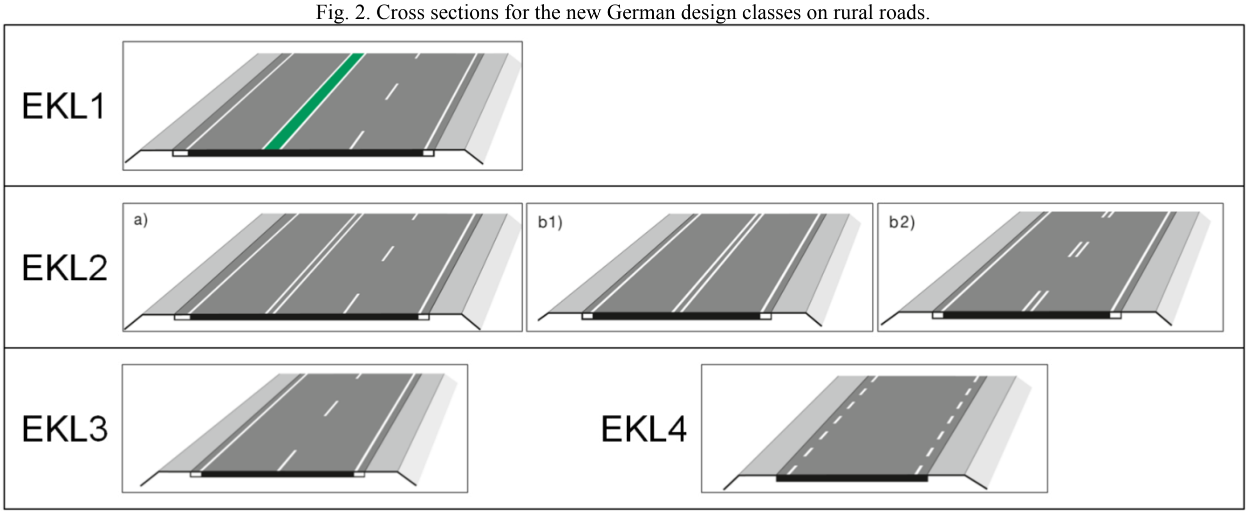
Due to the complexity of overtaking and the overlay of unfavorable factors of drivers, vehicles and the driving environment there are numerous ways in which an overtaking maneuver can lead to errors and accidents. Structural and operational measures on rural road can improve the perception of difficulties and draw the drivers' attention on problem areas, see Kämpfe et.al. (2005). Kayser and Struif (1993) differentiated infrastructural measures against overtaking in positive-acting (additional overtaking lanes) and negative-acting measures (restrictions on overtaking and speed limitations). Within AOSI-project the positive effects on overtaking accident causation by providing sporadic safe overtaking opportunities (additional overtaking lanes) with intervening sections with restriction on overtaking already been proven and confirmed by Lippold et.al. (2012).

3. German guidelines for design of rural roads

Since 2012 there are new guidelines for the design of rural roads 'RAL' in Germany, see FGSV (2012). The general increase of traffic safety and also measures for the securing of overtaking maneuvers are some of the main aspects in this guideline. Since the introduction of 'RAL' the design of rural roads is based on four defined design classes with recommended design features (cross sections, road alignment, type of intersection, traffic regulation). The determination of a design class for a new road depends on the road role within the whole road network. To focus on the context of this paper, this definition of four design classes is connected with fundamental principles on overtaking, which aims to ensure overtaking on overtaking lanes or avoid them in sections with critical overtaking sights.

The design class with the highest traffic importance (EKL 1, see Fig. 2) secures overtaking maneuvers continuously on an alternating middle overtaking lane in a three-lane cross section, which made approximately 40 % secure overtaking possibilities for each driving direction. On EKL 2 roads there are just partly overtaking lanes, which enable secure overtaking on approximately 20 % of each driving direction. Regarding the overtaking lanes there is a difference in road design compared to EKL 1 roads (see Fig. 2, EKL2/a). In the remaining two-lane parts of EKL 2 roads, driving in the lane of the oncoming traffic and finally overtaking is permitted by a line marking like in Fig. 2 (EKL2/b2). If there are insufficient sight distances for theoretically secure overtaking maneuvers overtaking can be prohibited by a central road edge marking (see Fig. 2, EKL2/b1). EKL 3 roads are conventional two-lane rural roads and generally the main part of the German road network outside of build-up areas. Here overtaking can be permitted in road sections with sufficient overtaking sight distances. On EKL 4 roads no needs for overtaking are designated, because they have the slightest traffic importance. All in all, overtaking in the lane of the oncoming traffic is generally possible on the two-lane sections at EKL 2 and EKL 3 roads with adequate overtaking sights by FGSV (2012).

Fig. 2. Cross sections for the new German design classes on rural roads.



Regarding the implementation of the new design class concept in the existing road network there are additional guidelines in development. Nevertheless, it can be assumed, that the implementation process of the new design classes on the existing road network will require a longer timeframe as mentioned in Richter and Zierke (2010). Therefore the task of the presented paper was to identify critical road features and tackle overtaking accidents for existing roads and also the new EKL 2 and EKL 3. Which design features and boundary conditions have to be considered for the prevention of overtaking accidents, is described in the context of this paper.

4. Macroscopic accident analysis

In a comprehensive road network analysis in the German federal states Baden-Wuerttemberg, Brandenburg, North Rhine-Westphalia, Rhineland-Palatinate and Saxony-Anhalt the most accident-prone road sections with relations to the overtaking process were determined. Therefore the accident databases of the years 2007-2009 were blended with the road information banks of the five federal states. Thereby 58,269 kilometers of two-lane rural roads were linked with 85,345 accidents with personal damage or serious property damage only.

The subset of overtaking accidents was identified through the supervening causes of the accidents, which are stated in the accident databases of the responsible police department. All in all, 6,200 overtaking accidents were filtered in the considered study area. For identifying the most accident-prone road sections the accident parameters were calculated and the accident cost density determined as selection criterion with the uppermost research capability. The result of this initially analysis was a ranking of the 500 rural road sections with the highest accident cost density of overtaking accidents which were used as a basis for further investigation steps.

4.1. Influence of road markings and signage

On the selected 500 road sections the present configuration of the traffic regulation (restrictions on overtaking and speed limits) were collected by own road inspections on a total length of 2,235 kilometers of rural roads. The evaluations showed that approximately on 70 percent of the investigated road sections overtaking is enabled and the remaining 30 percent were placed with restrictions on overtaking. If restrictions on overtaking are present, it is with 56 percent a marking (sign 295 German Highway Code), 22 percent a road sign (sign 276 German Highway Code) and the further 22 percent are a combination of road marking and signage. It has to be taken into account that a road marking by sign 295 German Highway Code just indicate that the drivers are not able to drive in the lane of oncoming traffic, so finally it is just an indirect overtaking restriction for e.g. two cars or a car and a trucks because of lane width restrictions. Nevertheless, cars and trucks are the main part of vehicles on rural roads, so finally this configuration of traffic regulation is also seen as a restriction on overtaking within this paper.

After the road inspections a total of 1,557 overtaking accidents are directly assigned to the individual road characteristics (restrictions). 76 percent of the overtaking accidents happened in road sections without any regulation, but the lack of restrictions was examined later in the sight distance analysis. 24 percent of the overtaking accidents were found in existing restrictions on overtaking. The analysis of the positions of the overtaking accidents together with the surveyed configuration of the traffic regulation showed a slightly higher accident conspicuousness of released sections as they are present in proportion to the road network. Subsequently accident parameters were calculated to clarify the accident conspicuousness of the different configuration of traffic regulation. The results are given in Table 1.

Table 1. Risk and severity of overtaking accidents at different configurations of traffic regulation

Traffic law arrengements on overtaking and speed	Speed limit [kilometer per hour]							
	100				90 80 70 60 50			
	Accident rate [Acc/(10^6·veh·km)]	Accident density [Acc/(km·a)]	Accident cost rate [€/(1,000·veh·km)]	Accident cost density [1,000€/(km·a)]	Accident rate [Acc/(10^6·veh·km)]	Accident density [Acc/(km·a)]	Accident cost rate [€/(1,000·veh·km)]	Accident cost density [1,000€/(km·a)]
Overtaking enabled	0.12	0.26	19.0	41.2	0.09	0.23	14.5	35.8
Overtaking prohibited and/or	0.09	0.21	14.9	37.4	0.06	0.18	9.2	27.0

Generally, there is a significant increase of traffic safety (vicarious through the calculated four accident parameters) when restrictions on overtaking or speed limits (main encountered configurations are 70/80 km/h, 50/60/90 km/h are very rare configurations) are placed in comparison to a decrease of safety in released road sections. The safety effects reach their maximum when both restrictions on overtaking and speed limits are ordered.

4.2. Influence of road design

In step of the research project a reproduction of the road layout at 100 accident-prone road sites had been carried out. This reproduction was the basis to check, which design parameters at accident locations are available and if the existing overtaking sights correspond to the configuration of traffic regulation on the road sections and whether the unity of road construction (existing sight) and road operation (configuration of traffic regulation) is ensured. To reach this, geographical point sequences were collected using GPS during the road inspections. These point sequences are rebuilt with a software for road design and the horizontal and vertical alignment of the road was recreated with all its design elements. Through an additional overlay with the road width and the lateral road design (implementation of roadside environment, sight obstacles and planting) a model of the road section arose.

The results of the road layout reproduction were section and sight tapes which were overlaid with the accidents and the configurations of the traffic regulation in order to obtain in depth information of accident-prone road characteristics and possible countermeasures. All in all, 350 kilometer of accident-prone road section were reproduced and 333 overtaking accidents had been allocated. The first conspicuousness's concerning overtaking accidents and the rural road layout and special features are shown in Fig. 3. Generally, there was the fact that overtaking accidents happen in a variety of road elements, which have a negative influence on the existing overtaking sights (combinations of curves, vertical curves and sight obstacles beside the road). Out of the considered 333 overtaking accidents 236 accidents occurred in horizontal curves. Here, the load of accidents generally increased with decreasing curve radii. Right-hand bends (based on the right-hand driving in Germany) are a little bit more accident-prone compared to left-hand bends, because the obstacle vehicle in the traffic flow is an additional obstacle for the sight too.

Further 114 overtaking accidents occurred in vertical curves (superimpositions between horizontal and vertical curves are possible). Within this both geometric elements of road layout overtaking is permitted in more than 70 percent of the investigated overtaking accidents. Just 26 - 29 percent had a restriction on overtaking (marking and/or signage restriction). Moreover 39 overtaking accidents occurred within the influencing zones of intersections, where overtaking is generally prohibited. But this was just the case in 54 percent of the concerned accidents.

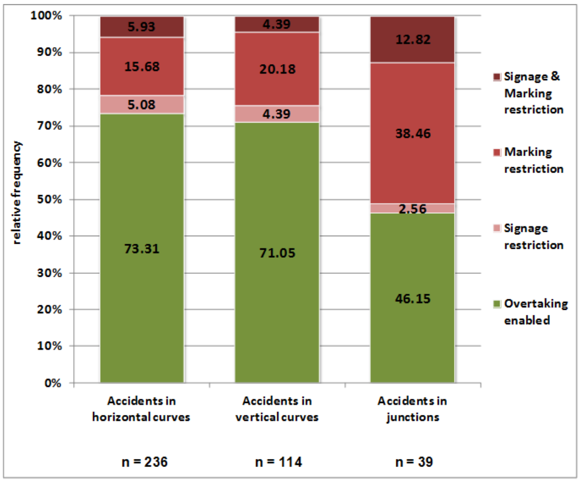


Fig. 3. Overtaking accidents at different road elements.

Another single influencing variable, which possibly have an effect on overtaking behavior and overtaking accidents, is the road width as reported by Palm and Schmidt (1999) and also Hegewald and Weber (2008). Within this project the cross-section design respectively the road width was also surveyed during the road inspections and matched to the standardized cross-section types of the last guideline generations for design of rural roads (RAS-Q 1982/1996), cf. FGSV (1982) and FGSV (1996). The reason for using just the older guideline generation was, that all considered road sections were planned in the past with these old guidelines. Within the matching process 57 percent of the considered road sections referred to the standardized cross-section types of RAS-Q (1996) and 30 percent to the standardized cross-section types of RAS-Q (1982). Further 13 percent of the road sections didn't have any conformity to the standardized cross-section types in the past guideline generations. The result of the accident parameter calculation for all identified cross-section types is depicted in Fig. 4.

It is recognizable that the accident rates and accident cost rates in Fig. 4 decrease with increasing road width respectively wider standardized cross-section types. Nevertheless, there are no clear tendencies for accident density and accident cost density. Relating to the accident rates and accident cost rates it can be assumed, the merely the higher traffic volume and the higher traffic importance of wide cross-section types leads to this result, because traffic volume is considered with its reciprocal in the accident rate calculation.

Together with the change of the road design guideline generation in Germany and the introduction of the four design classes (see also chapter 3) there was also a change of the standardized cross-section types. Here the cross-section type for EKL 3 (RQ 11) has nearly the same cross-section design like RQ 10.5 of RAS-Q (1996) (cf. FGSV, 1996), excepting a slight extension of the shoulder width of 0.25 m on both sides. The two lane section of EKL 2 is also wider dimensioned, because there is a doubled central marking which leads to a further extension of 0.50 m. Both cross-section types are the safest in Fig. 4.

The cross-section type RQ 9e2 with a road width of 6.00 m like in EKL 4 of RAL – cf. FGSV (2012) – belongs to the most unsafe cross-sections in Fig. 4. Nevertheless, for EKL 4 of RAL there are no regular overtaking maneuvers envisaged because of the new road marking type and the reduced planning speed of 70 km/h. Moreover, there would be a more centralized driving as reported by Zierke (2010) based on a before-after-comparison of driving behavior. That's why it can be assumed that the rata of overtaking would be very low on this cross-section type. More specific statements on overtaking accident occurrence on EKL 4 are not deducible in this project just based on the road width because the type of road marking was changed.

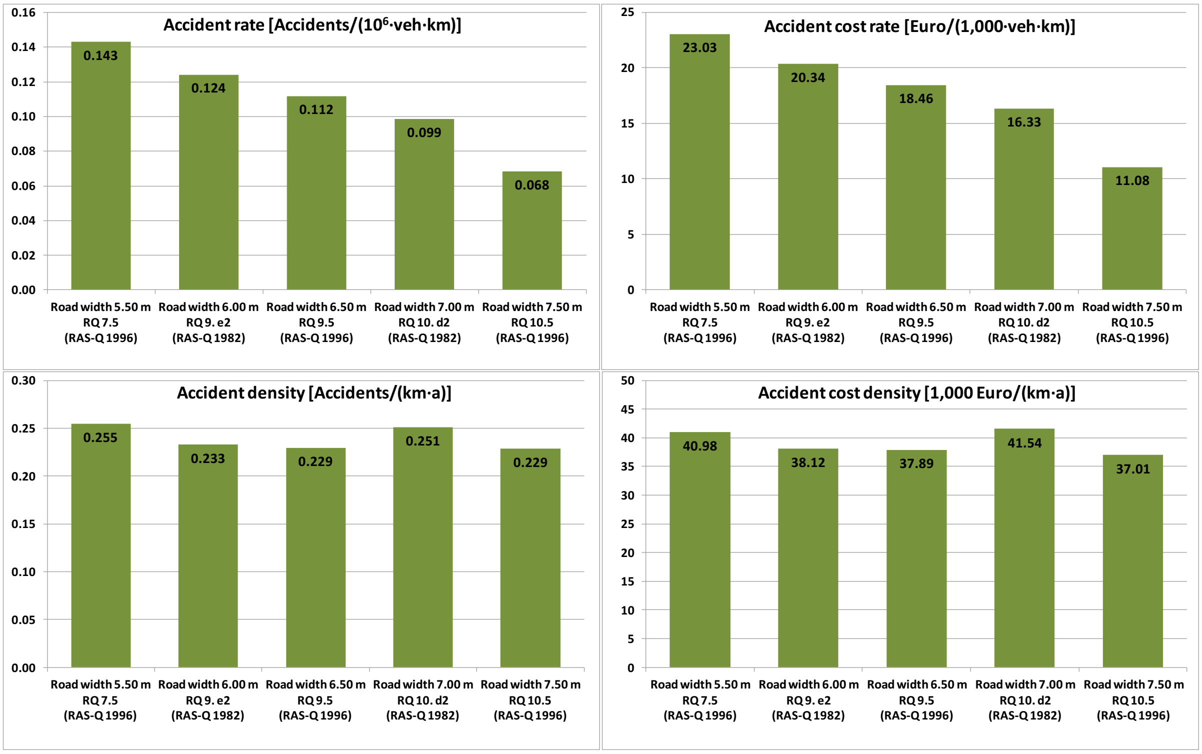


Fig. 4. Accident Parameters of overtaking accidents differentiated by standardized cross-section types of RAS-Q (1982) and RAS-Q (1996): (a) accident rate; (b) accident cost rate; (c) accident density; (d) accident cost density.

Generally, the comprehensive analysis of overtaking accidents whilst taking into account the road width showed some slight coherences, but it can be assumed that the road width is not sufficient as the only influencing variable for describing the overtaking accident occurrence. If there are for instance two road sections with the same traffic conditions and equivalent road width but with differenced horizontal curvature, there will be a different overtaking behavior and accident occurrence (severity) too.

Finally, the results of road width showed, that the occurrence of overtaking accidents cannot be described with just one influencing variables. Consequently, the accident occurrence is dependent on a superimposing of horizontal and vertical road design as well as the cross-section elements, which results in the existing sight distances. This superimposing of different influencing variables is considered below.

4.3. Influence of existing overtaking sight

After analyzing some single influencing variables, the main road layout elements had to be overlapped. The result of the overlay of horizontal and vertical curvature, the road width and the lateral road design are the existing sight distances, which were calculated within the road layout model. While changing the German guidelines on rural road design, the definitions on necessary overtaking sights had changed. Before the year 2012 the necessary overtaking sights depends on the 85 percent quantile speed, cf. FGSV (1995) and FGSV (1980). Within FGSV (2012) there are just two boundary values for sufficient sights for long overtaking maneuvers (more than 600 meters for overtake a car or a truck) and short overtaking maneuvers (more than 300 meters for overtake a slow agricultural vehicle). Within existing sights under 300 meters (half overtaking sight) overtaking should be prohibited. In general, the standards for necessary overtaking sights within the two guideline generations are just different for speeds under 100 km/h. The project results in Fig. 5 depends on the old definition, the new boundary values are just a little bit stricter, but there is an obviously result.

It can be quantified, that 24 percent of the overtaking accidents occurred in areas with insufficient overtaking sights (less than half overtaking sight). Further 46 percent of overtaking accidents are in the range between the half and full overtaking sight. The remaining 30 percent of the overtaking accidents should theoretically be carried out safely due to good sight conditions, what speaks for human misjudgments in the distance and speed of forthcoming vehicles as a significant cause of such accidents. Regarding the configuration of traffic regulation, there are more than 73 percent of overtaking accidents in areas with insufficient sights for normal overtaking maneuvers (below 600 m) but without any restrictions. This means that overtaking on cars and trucks is theoretically not possible with overtaking sights less than 600 meters, but the road operation conditions do not make the drivers aware of this. In accordance with the German Highway Code overtaking in the lane of the oncoming traffic should be prohibited, when the dangerousness of overtaking cannot be discerned by the driver independently and therefore overtaking maneuvers cannot be performed because of safety reasons, cf. StVO-VwV (2009). Due to historical increased road network, there is a lack of road markings and signage, when accident black-spots were identified.

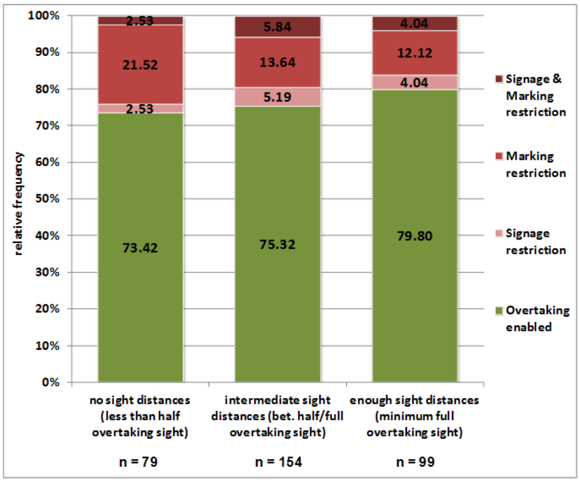


Fig. 5. Overtaking accidents within different overtaking sights.

Considering the element length of the configuration of traffic regulation and existing sights, the four accident parameters of Fig. 6 can be calculated. Generally, there are two main tendencies (just road sections with available annual average daily traffic data are considered). Firstly, the accident risk (in place of accident rate and density) and accident severity (in place of accident cost rate and cost density) decrease slightly with falling sights when no measures to avoid overtaking manoeuvres have been taken. Secondly through restrictions on overtaking obvious safety gains were appreciably in comparison to released road sections. In general, there are more sections with insufficient sights than sections with sufficient sights, that's why the accident parameters are decreasing, because there are a lot of sections without accidents, which were also considered in this network reflection. But there are two exceptions. The accident risk is nearly at the same level for sections without overtaking regulatory measures. Moreover and in consideration of the accident severity there are no differences between permitted and prohibited overtaking in sections with sufficient overtaking sights. The risk is lower, but if accidents occur they have similar consequences. Especially in the sections with slight up to mean sight conditions clear restrictions are required to support the drivers, because the most overtaking accidents occurs here.

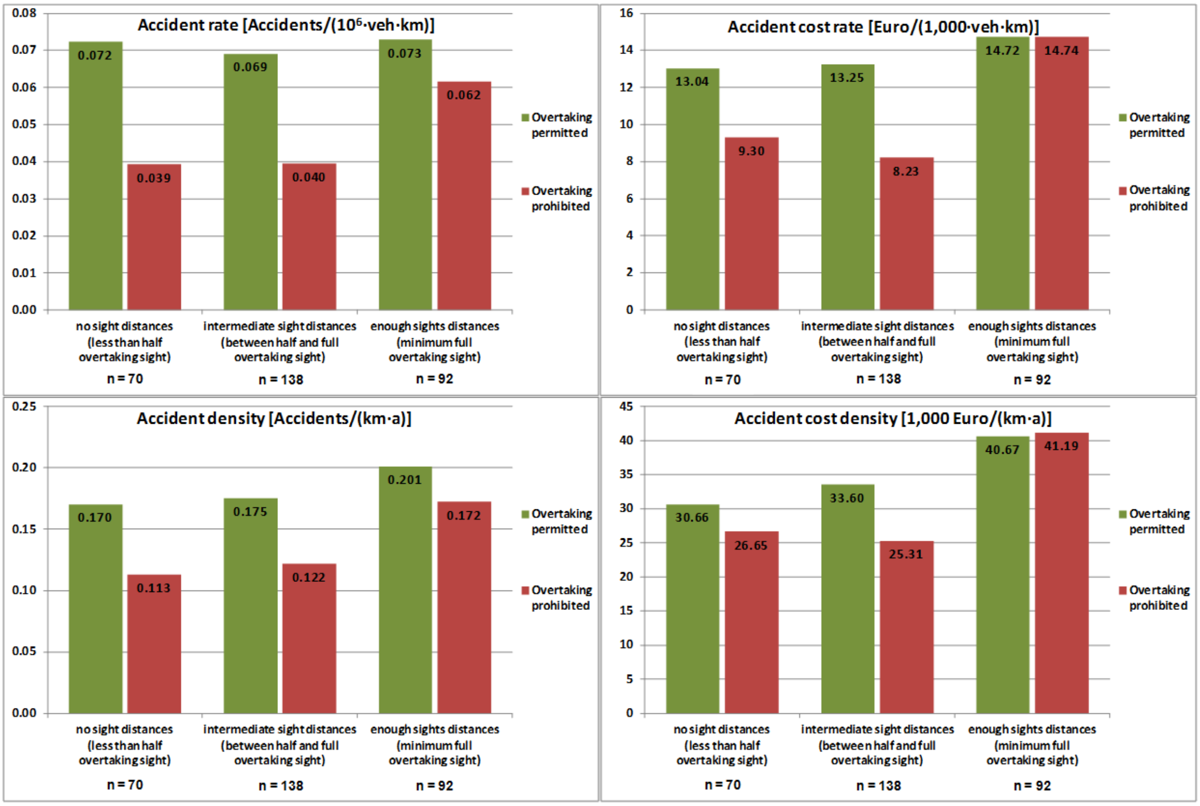


Fig. 6. Accident Parameters of overtaking accidents differentiated by configurations of traffic regulation and existing overtaking sights: (a) accident rate; (b) accident cost rate; (c) accident density; (d) accident cost density.

5. Microscopic accident analysis

After completion of the sight tape analysis 50 road sections have been selected by means of a clustering, on which microscopic accident analyses and later detailed analyses of the overtaking behavior were carried out. The analysis of details of how the accidents occurred (police data and accident descriptions of 166 overtaking accidents) showed the following results.

In the most cases (97 percent) the overtaking vehicle caused the accidents solely, the remaining 3 percent were a partial blame. Therefore, the overtaking driver can be generally seen as the accident main responsible. This accident main responsible are mostly drivers of cars (82 percent), 13 percent motorcycles and 5 percent trucks. The decisive corresponding obstacles in traffic flow (vehicles which was overtaken) were by 54 percent cars, 31 percent trucks, 5 percent agricultural vehicles and 4 percent light motorcycles.

The further evaluation of the 166 accident descriptions results in 5 authoritative types of collision of overtaking accidents (visible in Fig. 7). Collisions with oncoming traffic are with 42 percent the largest group. Fundamental problems are here incorrect decisions in accepting or rejecting potential overtaking opportunities due to incorrect sight distance and speed estimation of the drivers. The other four influential collision types are more or less evenly distributed (the remaining two types are just exceptional cases, which are not considered here). These four collision types are collisions with turning vehicles (overtaking vehicle not recognized the turning intention), collisions with already overtaking vehicles (rear overtaking), collisions with road environment (loss of control while overtaking with sliding off the road) and collisions with the obstacle vehicle (swing out and also the process of going back into the own lane in connection with inadequate safety distances). Collisions with rear overtaking vehicles are with 52 percent with the involvement of motorcycles. Here, the high weight-acceleration-ratio compared with a car has the most negative influence together with insufficient orientation of the driver in the further overtaking vehicle. The collision opponents at overtaking accidents with left turning vehicles are with 55 percent cars, 22 percent agricultural vehicles and 15 percent trucks. Especially agricultural vehicles are problematic here because they often turning unexpectedly into inconspicuous agricultural roads.

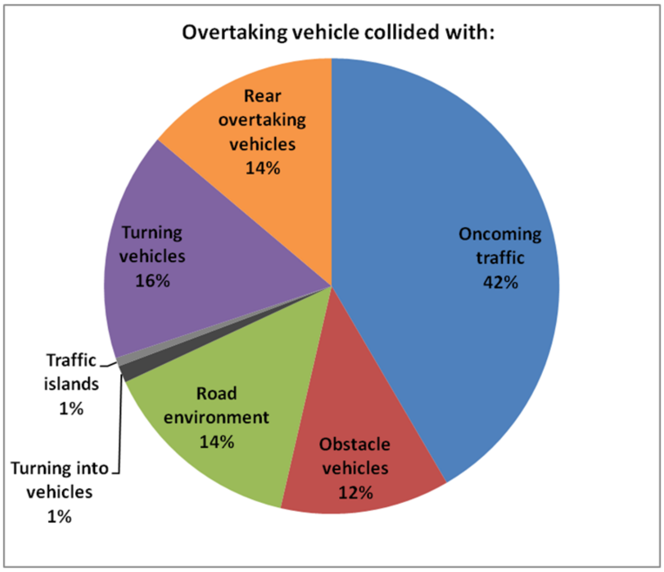


Fig. 7. Collision types of overtaking vehicles.

Some more facts can be mentioned as follows. With participation of motorcycles (comparatively vulnerable road users at rural roads) and trucks (high kinetic energy) the accident severity increases as expected. In general, 69 percent of the cases of accidents only one obstacle vehicle was overtaken. Further 19 percent of accident main responsible overtake two vehicles and at 12 percent more than two obstacle vehicles are stated directly in the accident descriptions. Overtaking a line of cars is seen as very dangerous, because the length of the necessary overtaking path is very difficult to estimate for drivers. Generally, 48 percent of the overtaking accidents occurred during the direct overtaking manoeuvre (passing process), 27 percent during the swing out process and 19 percent during the process of going back into the own lane. For the remaining 6 percent none of the relevant phases of overtaking could be clearly assigned.

Young drivers are particularly prone to overtaking accidents. About half (46 percent) of accident main responsible are younger than 30 years. 85 percent of the overtaking accidents were caused by men. The proportion of overtaking accidents by contempt on existing restrictions on overtaking is with 53 percent the highest by novice drivers (under 20 years old). In general, for young drivers the main difficulties exist in the estimation of sufficient required length of overtaking paths, because of missing driving experiences. Older people tend to lacks of orientation in the traffic-related environment.

Finally, the identified basic problems of overtaking accidents are miscalculations of drivers (especially existing overtaking sights and also distance and speed of oncoming traffic), the loss of control, insufficient safety clearances and the lack of orientation in the surrounding traffic (conflicts with turning or already rear overtaking vehicles as well as conflicts at swing out and the process of going back into the own lane).

6. Analysis of overtaking behavior

During the detailed analysis of overtaking behavior, 10-hour surveys on rural roads were performed to get hints about the boundary conditions where overtaking maneuvers take place. Therefore a differentiation was made between road sections with and without overtaking opportunities (road sections with sufficient overtaking sights and by law permitted overtaking confronted with road sections with insufficient sights or by law prohibited overtaking). The main goal was to make relationships between the overtaking quantity and the road design characteristics.

All in all 15,173 overtaking maneuvers in about 78 road sections were identified (some of the initial 50 road sections were subdivided by the above mentioned criteria) and associated with the road characteristics. The dividing of overtaking maneuvers into different car classifications (active/passive overtaking vehicle) resulted in decisive 34 percent car/car-overtaking maneuvers, 37 percent car/truck-overtaking maneuvers, 17 percent overtaking of cars at light motorcycles or agricultural vehicles and finally 7 percent motorcycle/car-overtaking maneuvers. The other combinations of vehicle classes are rather underrepresented. For the following evaluations just defined representative overtaking maneuvers are considered (subset of 12,315 overtaking processes). These are overtaking maneuvers which require a long overtaking path due to slight speed differences between the active and passive overtaking vehicle. These cases can be seen as the most critical maneuvers. As an example, car overtaking maneuvers at slow light motorcycles or agricultural vehicles are seen as comparatively uncritical due to high speed differences and consequential short overtaking paths.

As a further result, the number of accidents and representative overtaking maneuvers was reported for various design characteristics of the investigated road sections. Therefore the considered road sections were divided in the above mentioned three categories of existing overtaking sights (see Fig. 8a). Basically the number of overtaking maneuvers as well as the overtaking rate (considering the length of analysed road sections) increases with better visibility. Nevertheless, in all sections of existing sights overtaking accidents occurs. The connection of overtaking accidents and overtaking maneuvers quantify an accident risk per overtaking, so the reported accident risk decreases significantly with increasing sight distances (Fig. 8b).

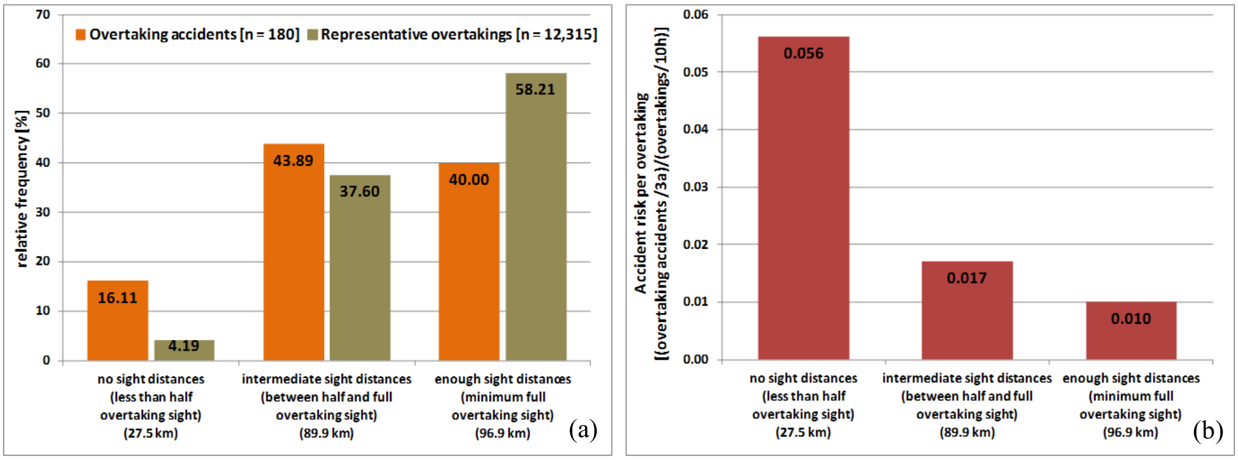


Fig. 8. Overtaking accidents and maneuvers differentiated in: (a) overtaking sights; (b) relationship between both parameters.

This potential risk is a value for estimating the risk of accidents per individually overtaking maneuvers. Thereby it has to be advised that the different periods which are under consideration (accidents within three years and overtaking maneuvers within ten hours) have to be considered. There would be the possibility to match both periods through extrapolation, but no matter which factor would be set, the tendencies will be the same.

In general, due to the weak overtaking behavior but nevertheless comparatively large numbers of overtaking accidents in sections with insufficient sights the accident risk during an overtaking maneuver increases. But even with only a few overtaking maneuvers a need of restrictions on overtaking arises to prohibit these maneuvers in sections with slight up to mean overtaking sights. Restrictions on overtaking revealed in total a significant decrease of overtaking accidents and maneuvers.

But unfortunately it has to be referenced, that road markings and signage as arrangements for traffic regulation can reduce the number of overtaking maneuvers but cannot invariably suppress the overtaking behavior. Independently from the kind of restrictions on overtaking 2,25 overtaking maneuvers per kilometer and hour could be ascertained in this sections during the empirical surveys. The amount of overtaking maneuvers in prohibited sections fluctuates dependent on other road boundary conditions like existing sight distance. The most drivers act on the given configuration of traffic regulation, but if there are just particular drivers who disregard the precepts there is a high danger of fatal overtaking accidents. Generally, acceptance problems for the chosen measures had to be declined here due to additional modular measures (e.g. additional speed limits by lasting accident black-spots).

7. Recommendations and measures tackling overtaking accidents

The recommendations of this paper are focused on infrastructural and operational measures to tackle black spots concerning overtaking accidents and general suggestions, where these measures should be applied. The results of this study clarified, that the existing overtaking sight is the road design feature with the main impact on overtaking safety. Moreover, the accident analysis points out a disunity of road construction (existing overtaking sights) and road operation (configuration of traffic regulation). Beside the complex process of situational assessment, the following weighting and the decision about acceptance or refusal of an overtaking possibility this lack of restrictions intensifies the overtaking behavior negatively. The network analysis yielded to a catalogue of specific measures, which are summarized below.

The risk of overtaking accidents is high. That´s why restrictions on overtaking are needed in road sections with insufficient overtaking sights (sights below the necessary full overtaking sight of 600 meters). With respect to slow driving vehicles (agricultural vehicles) the measures had to be divided in general restrictions on overtaking in sections with sights below the half overtaking sight (300 meters) and partially restrictions on overtaking with the release of overtaking at slow (e.g. agricultural) vehicles at intermediate sights (300 up to 600 meters). The restrictions had to be announced by arrow markings in the forefront to inform the driver early enough about the dangerousness of the following road section. These recommendations must be implemented strictly with renewed or generally newly constructed roads and at black spots on existing roads. But the results showed the need of additional measures at accident-prone road sections with already existing overtaking regulations too. Here, the efficacy of the existing measures has to be reinforced. Beside road markings and signage an additional speed limit can also reduce the risk of overtaking accidents and contain the overtaking behavior, because they reduce the speed dispersion and lead to a harmonized traffic flow. The safety impact of both measures was demonstrated within this report. Generally, all the above mentioned measures can improve traffic safety at black spots in the short-term.

Moreover, there are some other specifics of road design features, which have a negative impact on overtaking maneuvers too. Within the own road inspections there were road sections which attract attention, because they are equipped with existing restrictions on overtaking (road markings by dividing lines), but these restrictions are interrupted by broken lines for a length of 200 meters (with steady inadequate sights). Those interruptions had to be closed because drivers may think that overtaking is not prohibited anymore, so they have a potential possibility to overtake. This can lead to misunderstandings and causes accidents. Consistent and comprehensible measures are needed instead.

At existing roads there is the possibility that available overtaking sights can be reduced by half abruptly, if there is an unfavorable functional interaction of horizontal, vertical and lateral road design. Those road sections must be restricted on overtaking maneuvers, because there is a high risk of overtaking accidents due to suddenly disappeared or appeared oncoming traffic behind sight obstacles.

Generally, there is a need of preventive measures within the range of influence of intersections to secure traffic flow at road sections where the overtaking pressure arises due to increasing speed dispersion (speed of the turning vehicle). The necessity of measures is heightened at inconsiderable road turn-offs.

Nevertheless, there are overtaking accidents in road sections with sufficient overtaking sights too. If there are accumulations of overtaking accidents in those sections there will be a need of so called positive-acting measures like additional overtaking lanes, where overtaking maneuvers can be performed safely. Those additional overtaking lanes are mostly long-term measures for rural roads with higher traffic importance and accordingly higher traffic volume. These measures require building works and cause corresponding costs.

Beside infrastructural and operational measures the driver education is important to highlight the general risk of overtaking maneuvers using the lane of the oncoming traffic, especially for young inexperienced drivers. If accumulations of disregards of existing restrictions are visible the enforcement plays an important part. Unlawful overtaking in ‘prohibited’ road sections must be punished hard, but there is still a lack of methods for its control.

8. Conclusion

Overtaking accidents are usually very serious accidents on rural roads. They occur mostly in road sections where overtaking is permitted. The analyses revealed that a large proportion of overtaking accidents occurs in areas with insufficient overtaking sights and where no configurations of traffic regulation have been taken to counter overtaking maneuvers. But the assumption that drivers can detect insufficient overtaking sights independently and therefore does not begin to overtake is wholly inadequate, because the complex weighting process of existing overtaking possibilities containing errors. Miscalculations of overtaking sights as well as speed and distance to oncoming vehicles are here the main problem areas. Missing configurations of traffic regulation can negatively warp the drivers' perception. Instead, the drivers must be supported in road sections with insufficient overtaking sights through operational measures in their task of driving. With the introduction of road design classes and the associated principles of overtaking in the guidelines for the design of rural roads in Germany (RAL) serious overtaking accidents can be avoided by clear precepts on overtaking and the safety of rural roads will increase.

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